

**CLOUD ATLAS**

for the

**FIRE Cirrus Intensive Field Observation****October 5 - November 10, 1986**

An Intensive Field Observation (IFO) of cirrus clouds was conducted over the mid-western U.S. during the period October 13 - November 2, 1986. This activity, part of the First ISCCP Regional Experiment (FIRE), included measurements made from specially deployed instruments on the ground, balloons, and aircraft as well as observations from existing operational and experimental satellites. The satellite observations were collected for the purposes of the IFO beginning 1 week prior to and ending 1 week after the IFO period. In addition, there were satellite observations collected on the 5th to the 10th and 20th to the 25th of each calendar month as part of the FIRE Extended Time Observations, which cover a region that encompasses the Cirrus IFO area. As a result, the collected satellite data include daily coverage over a 37-day period from October 5 to November 10, 1986.

One of the sets of satellite observations was the radiance measurements made with the 5-channel AVHRR radiometer on the NOAA 9 polar orbiting meteorological satellite. These data were collected from NOAA ground stations at Wallops Island, Virginia, and Redwood City, California, during satellite overpasses. The ground resolution of the measurements at nadir is approximately 1 km. It is these measurements, made once each day at approximately 2:30 p.m. local time, that were used in determining the present cloud atlas. The area covered by the atlas is slightly larger than the area specified for the IFO, in order to be in alignment with the grid that will be used in a forthcoming atlas for the larger, ETO region. The present atlas covers the area from 37.5 - 47.5 N and 80 - 105 W, which includes 8 x 15 *analysis boxes* out of the 16 x 48 boxes that constitute the ETO region. Each *analysis box* covers 1.25° latitude by 1 2/3° longitude, which is an area approximately 140 km square. There are from 5,000 to 22,000 pixels within each box (except where there is missing data), the amount depending on the position of the box with respect to the satellite track.

The retrieved parameters for each pixel include:

- $f$  fraction of pixel covered by cloud
- $\tau$  cloud optical thickness
- $T_c$  cloudtop temperature
- M cloud microphysical model

The three parameters are retrieved from the visible [Ch. 1] and thermal infrared [Ch. 4] channels using the *maximal clustering method*, described in Arking and Childs (1985), with some refinements that will be described in a forthcoming publication. A fourth parameter, the microphysical model (MPM) index  $m$ , represents information concerning the particle size and phase of the cloud particle, which is assumed to be spherical with a size distribution given by

$$\frac{dN(r)}{dr} \propto r^6 \exp[-6 r/r_o]$$

where  $N(r)$  is the number of particles per unit volume with radii smaller than  $r$ , and  $r_o$  is the mode radius. For this distribution the mean radius is  $7/6 r_o$ , and the effective radius is  $3/2 r_o$ .

The MPM index is retrieved as a single parameter for the *analysis box* as a whole, representing the best fit for all points to the observed  $3.7 \mu m$  [Ch. 3] radiance measurements, as described in Arking and Childs (1985). There are five possible values of  $m$ , representing the following combinations of particle size (mode radius  $r_o$ ) and phase (water/ice):

<u><math>m</math></u>	<u>MPM</u>
1	$4 \mu m$ water
2	$4 \mu m$ ice
3	$8 \mu m$ water
4	$8 \mu m$ ice
	$16 \mu m$ water
5	$32 \mu m$ ice

The atlas contains four pages of information for each satellite pass. The satellite pass is identified at the top of each page by date, time (GMT) at which the satellite crosses  $40^\circ$  N latitude, satellite (NOAA 9 in each case), and orbit number. The 1st page of each group shows the distribution of measured radiances in channel 1 (normalized to the incoming solar flux multiplied by the cosine of the solar zenith angle) and in channel 4 (expressed as a brightness temperature in degrees  $K$ ) for the area as a whole and for each *analysis box*. The 2nd page shows the images in: channels 1 and 2, combined to form a color image as described in Arking, Childs, and Merritt (1987); channel 3R, which represents channel 3

after subtracting out the emitted radiance based upon the channel 4 brightness temperature and normalizing to the incoming solar flux multiplied by the cosine of the solar zenith angle; and channel 4, the  $11 \mu m$  brightness temperature. The 3rd page shows the retrieved parameters in *graphical* form for the region as a whole and for each *analysis box*, where cloud fraction appears as a contour plot with respect to optical thickness and cloudtop temperature. The 4th page provides a statistical summary of the retrieved parameters in *numerical* form for each *analysis box*.

The entries are as follows:

#### Cloud Amount

Total cloud amount is shown for all values of  $f$  and for  $f$  restricted to the range  $0.9 \leq f \leq 1$ . A large difference between the two values indicates that most of the cloud cover is associated with sub-pixel resolution clouds, thus suggesting greater uncertainty in the results.

#### Optical Thickness

The optical thickness, in the visible channel ( $0.63 \mu m$ ), mean and standard deviation, based upon plane parallel radiative transfer theory. (For any pixel, it is inversely related to cloud amount.)

#### Cloudtop Temperature

Cloudtop temperature, mean and standard deviation, based upon a cloud infrared emissivity derived from the visible channel optical thickness using Mie theory.

#### Surface Parameters

The mean visible channel reflectance and infrared channel equivalent blackbody temperature associated with clear-sky conditions. An asterisk indicates that the algorithm failed to identify clear-sky conditions and used default values.

#### Number of Pixels

The number of pixels in the analysis, which is affected by viewing geometry.

### Number of Clusters

The number of clusters that were found by the cluster detection algorithm and used in the analysis. An asterisk indicates failure to detect any clusters (other than the surface cluster) and consequent use as default the clusters derived from analyzing the entire region as one box.

### Cosine of Satellite Zenith Angle ( $\mu$ )

Mean value of the cosine of the satellite zenith angle measured from the target point. Values less than 0.5 or 0.6 indicate poor viewing geometry.

### Model Index

The mode value of the MPM distribution. Note that all pixels associated with a single cluster are assigned the same MPM.

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### References

Arking, A., and J. D. Childs, 1985: Retrieval of cloud cover parameters from multispectral satellite images. *J. Climate Appl. Meteor.*, **23**, 322-333.

Arking, A., and J. D. Childs, and J. H. Merritt, 1987: Remote sensing of cloud cover parameters. *Atmospheric Radiation Progress and Prospect. Proceedings of the Beijing International Radiation Symposium*, ed. by K.-N. Liou and Z. Xiuju, 473-488, Science Press, Beijing.

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